Changes in vegetation following reductions in white-tailed deer abundance at Eagle's Crest and Spring Pond Nature Preserves, Eagle Creek Park, Indianapolis, Indiana

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October 11, 2016

Introduction

Between November 28, 2014 and January 20, 2015, controlled hunts were conducted at Eagle Creek Park to reduce the abundance of white-tailed deer (*Odocoileus virginianus*), resulting in the harvest of 249 deer (186 does and 63 bucks). This hunting program was initiated to reduce the negative impacts of overabundant deer on Eagle Creek Park and restore the balance of the Park's ecosystems (Department on Public Works 2014).

In June and July of 2013, I assessed vegetation on permanent plots within two areas of Eagle Creek Park to document the effects of the overabundant deer population on plant communities. This assessment included measuring the height of indicator species, tallying the density of seedlings and saplings, and assessing the occurrence of browse on woody twigs. In June and July of 2016, I resampled these plots to assess changes in vegetation following the reduction in deer abundance.

Methods

This study was conducted in Eagle's Crest and Spring Pond Nature Preserves (Figure 1). Eagle's Crest NP is a 296 acre (120 ha) late-successional forest reserve comprised of ridges and ravines. Spring Pond is a 44 acre (18 ha), poorly-drained forest located east of the Eagle Creek Reservoir. After their establishment, both preserves were closed to hunting.

I resampled vegetation in both nature preserves to quantify: (1) changes in the condition of vegetation communities based upon indicator species, (2) changes in woody species composition and stem density in forest understories, and (3) changes in the frequency of browse on woody species in forest understories.

Indicator species

To evaluate browse severity based upon herbaceous indicator species, I followed the methods of Webster and Parker (2000) and Webster et al. (2001). Specifically, I measured the heights of two species; jack-in-the-pulpit (*Arisaema triphyllum*) and white baneberry (*Actaea pachypoda*). Although sweet cicely (*Osmorhiza claytonia*) is also an indicator, I observed too few individuals of this species to use it in the analysis.

I measured all mature jack-in-the-pulpit plants within variable radius plots (ranging from 10 to 15 m depending upon the abundance of focal species) that used the same center points as permanent plots established by Dolan and Moore (2007a, 2007b; Figure 1). Jack-in-the-pulpit was abundant at Eagle's Crest NP and fairly common at Spring Pond NP. However, I only observed sporadically baneberry at Eagle's Crest NP. Therefore, I measured all individuals of this species that I encountered both on and off the plots. I also performed systematic searches at Spring Pond NP to increase the number of jack-in-the-pulpit plants measured. I measured a total of 900 jack-in-the-pulpit plants at Eagle's Crest NP and 102 plants at Spring Pond NP. I

measured 18 baneberry plants at Eagle's Crest NP. I also noted whether plants were flowering and/or had been browsed. The gender of jack-in-the-pulpit plants was also identified.

Figure 1. (A) Eagle's Crest and (B) Spring Pond Nature Preserves. Sample grid locations from Dolan and Moore (2007a, 2007b) are shown for both Preserves. Points A3, A4, B2, G3, G5, G6, H7, H8, and H9 were sampled at Eagle's Crest NP. Points A1, A3, A9, C7, C8, C9, F2, and F5 were sampled at Spring Pond.

Mean heights were calculated for each species, and adjusted percent cover (APC) was calculated using regression equations developed by Webster and Parker (2000). For this analysis, a single mean height was determined for all 900 jack-in-the-pulpit and 18 baneberry plants at Eagle's Crest NP and all 102 jack-in-the-pulpit plants at Spring Pond NP.

Jack in the pulpit:

APC = 1.234(mean plant height) - 12.07

White baneberry:

APC = 0.806(mean plant height) + 8.737

APC was used to estimate the browse damage class of each preserve based upon ranges provided by Parker and Webster (2000) and Webster et al. (2001).

To statistically examine changes in jack-in-the-pulpit height, I used paired t-tests with $\alpha = 0.05$ to compare plot mean heights by sample year (2013 and 2016) at both preserves (n = 9 plots at Eagle's Crest NP and n = 8 plots at Spring Pond NP).

Understory woody species composition and stem density

A nested plot design was used to sample understory woody vegetation. Stems ≥1m in height (saplings) were tallied by species into two diameter classes (≤2.5 cm dbh and stems 2.6-10 cm dbh) within either a 300 m^2 (9.77 m radius) or a 200 m^2 (7.98 m radius) plot, depending upon stem density. Four 4 m^2 quadrats positioned four meters from plot center in cardinal directions were used to tally seedlings (stems <1 m height) into two height classes; 0-20 cm and 21-100 cm. Mean density of saplings per hectare was calculated by species for each diameter class. Mean density per 100 m^2 was calculated by height class for each seedling species. I used paired t-tests with $\alpha = 0.05$ to compare mean total seedling and sapling densities (all species combined) by sample year (2013 and 2016) at both preserves (n = 9 at Eagle's Crest NP and n = 8 at Spring Pond NP).

Woody species browse

Browsing of woody understory stems was assessed in four 2 x 2 m quadrats placed in cardinal directions four meters from plot center. The techniques of Williamson and Hirth (1985) were used to quantify browse of individual twigs. Available (non-browsed) and browsed twigs (0.15 to 1.8 m above ground) were counted by species from up to eight randomly selected individuals per species. All woody species were quantitatively assessed except spicebush (*Lindera benzoin*), a non-preferred species, and paw paw (*Asimina triloba*), a highly non-preferred species. Based upon field observations, I noted light to intermittent browsing of spicebush and no browsing of paw paw. Percent of twigs browsed for each species was calculated as a per plot average. I used paired t-tests with $\alpha = 0.05$ to compare plot mean percent browse (all species combined) by sample year (2013 and 2016) at both preserves (n = 9 at Eagle's Crest NP and n = 8 at Spring Pond NP).

Results and Discussion

Indicator species

The mean height calculated from all 900 jack-in-the-pulpit plants at Eagle's Crest NP was 18.0 ± 2.4 cm, which was greater than the mean calculated from all plants in 2013 (16.1 ± 2.3 cm). When this value was inserted as the independent variable into the regression equation developed by Webster and Parker (2000), APC was estimated as 10.2%, which corresponded to

a browse damage rating of severe (the lowest rating; Webster et al. 2001), but was an improvement over the 2013 APC of 7.8%. The mean height of all pooled jack-in-the-pulpit plants at Spring Pond NP was 13.7 ± 1.9 cm in 2013, but increased to 14.7 ± 2.1 cm in 2016. According to the regression equations developed by Webster and Parker (2000), this value equates to an APC of 6.0%, which also corresponds to a damage class rating of severe, but was an improvement over the 4.8% APC calculated from the 2013 data.

The per plot mean height of jack-in-the-pulpit plants at Eagle's Crest NP (n = 9 plots) was 19.0 ± 0.8 cm in 2016, which was greater than the mean height of 16.4 ± 0.4 cm observed in 2013 (Figure 2; p = 0.01). The mean height of jack-in-the pulpit plants at Spring Pond NP (n = 8 plots) also increased from 13.7 ± 0.5 cm in 2013 to 15.4 ± 0.7 cm in 2016 (p = 0.07; Figure 2). For both sites, this increase in mean height resulted from a lower proportion of plants less than 16 cm in height in 2016 combined with an increase in the proportion of plants between 18-26 cm in height (Figure 3).

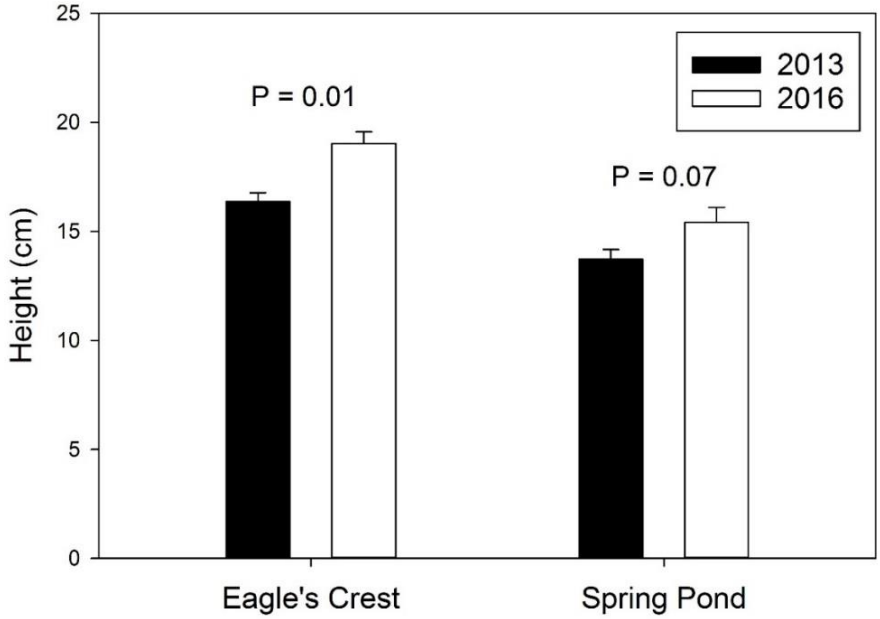

Figure 2. Mean height (± 1 SE) of jack-in-the-pulpit plants calculated by plot from data collected in 2013 and 2016. Means were compared by sample year for each site with a paired t-test.

At Eagle's Crest NP, only 1.8% of jack-in-the-pulpit plants were flowering in 2013, but in 2016 3.4% were flowering. The ratio of male to female plants remained similar between years; 16.7% of flowering plants were female in 2013 vs. 16.2% in 2016 (Figure 4). In both 2013 and 2016, few plants were flowering at Spring Pond NP (three plants in 2013 vs. 1 plant in 2016).

Similar to jack-in-the-pulpit, the mean height of baneberry plants at Eagle's Crest NP increased from 15.8 ± 1.4 cm (based upon four plants) to 18.9 ± 1.4 cm (based upon 18 plants). This produced an APC estimate of 24.0%, compared to 15.8% in 2013, which constituted an improvement from the severe to the heavy impact class as described by Webster et al. (2001).

Increases in height growth and flowering of indicator species were observed in 2016, two years following the deer population reduction in 2014. While the relationship between the height of forest plants and deer abundance has been well established (Webster and Parker 2000, Webster et al. 2001, Jenkins et al. 2007, Heckel et al. 2010), other environmental variables influence the growth of plants by altering the allocation of biochemical resources (Weiner 2004). Continued monitoring of indicator species height and demography over successive years is needed to track community response to continued efforts to reduce and maintain sustainable deer population abundance.

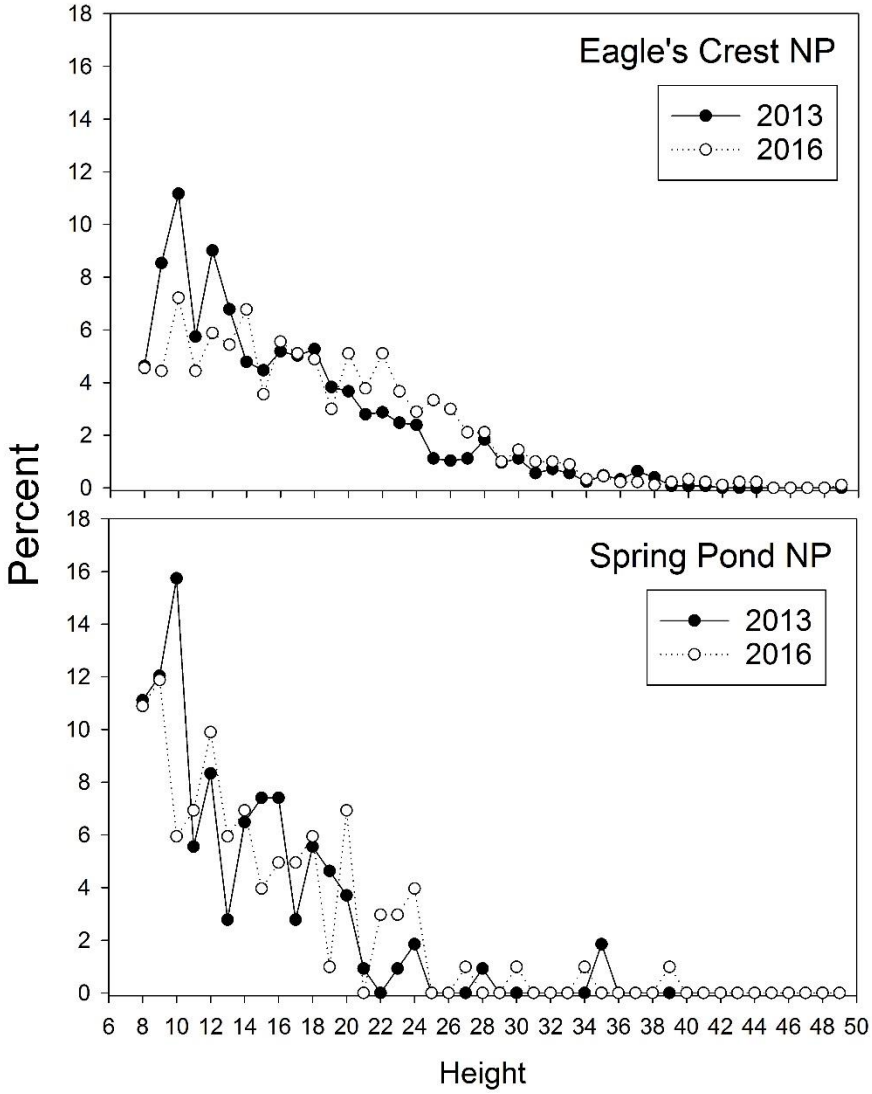

Figure 3. Percent distribution of jack-in-the-pulpit plant heights at Eagle's Crest and Spring Pond Nature Preserves. Both sites exhibited a reduced proportion of smaller plants in 2016 compared to 2013.

Figure 4. Female jack-in-the-pulpit plant at Eagle's Crest NP. The proportion of flowering plants at Eagle's Crest NP increased between 2013 and 2016.

Understory woody species composition and stem density

Eagle's Crest NP

Between 2013 and 2016, the density of small seedliings (0-20 cm height) increased dramatically at Eagle's Crest NP from 71 ± 29 stems/ha to 316 ± 85 stems per 100 m^2 ($p = 0.01$). This increase was mostly the result of large increases in the densities of ash (*Fraxinus* spp.) and sugar maple (*Acer saccharum*) seedlings (Figure 5). The density and composition of the forest seedling layer are highly variable from year-to-year and are influenced by a variety of biotic and abiotic factors (Clark et al. 1999). Jenkins et al. (2015) observed a large increase in the density of ash seedlings after the initiation of deer hunting in Indiana state parks, but a similar increase also occurred over the same time period in reference areas with a long history of deer hunting. However, an exclosure study revealed that heavy deer herbivory was associated with reduced

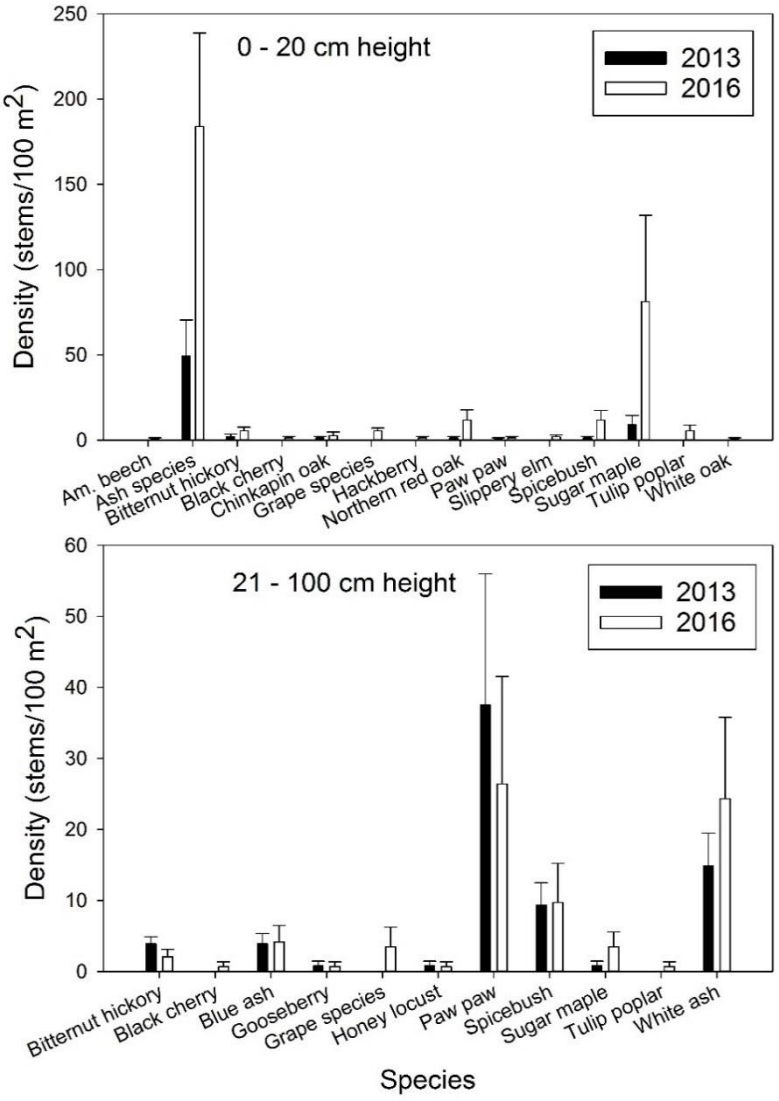

Figure 5. Density (mean ± 1 SE) of small (0-20 cm height) and large (21-100 cm height) woody seedlings by species at Eagle's Crest NP in 2013 and 2016.

sugar maple seedling density in Potato Creek State Park in northern Indiana (Riemenschneider et al. 1995). The number of species tallied in this layer increased from 8 in 2013 to 15 in 2016. Over a 13 year period, Jenkins et al. (2015) also observed an increase in species richness following deer population reductions in Indiana state parks. Unlike small seedlings, large seedlings (21-100 cm height) exhibited little change in density (66 ± 25 stems/100 m^2 in 2013 vs. 76 ± 27 stems/100 m^2 in 2016; $p = 0.12$). Similar to large seedlings, there was little change in the sapling layer of Eagle's Crest NP between 2013 and 2016 (Figure 6). For small saplings (≥1 m height; 0-2.5 cm dbh), density per ha of stems was 585 ± 160 in 2013 and 540 ± 177 in 2016; p =

0.48). Likewise, the density of large saplings did not change significanlty (282 ± 67 stems/ha in 2013, 328 ± 111 in 2016; p = 0.55).

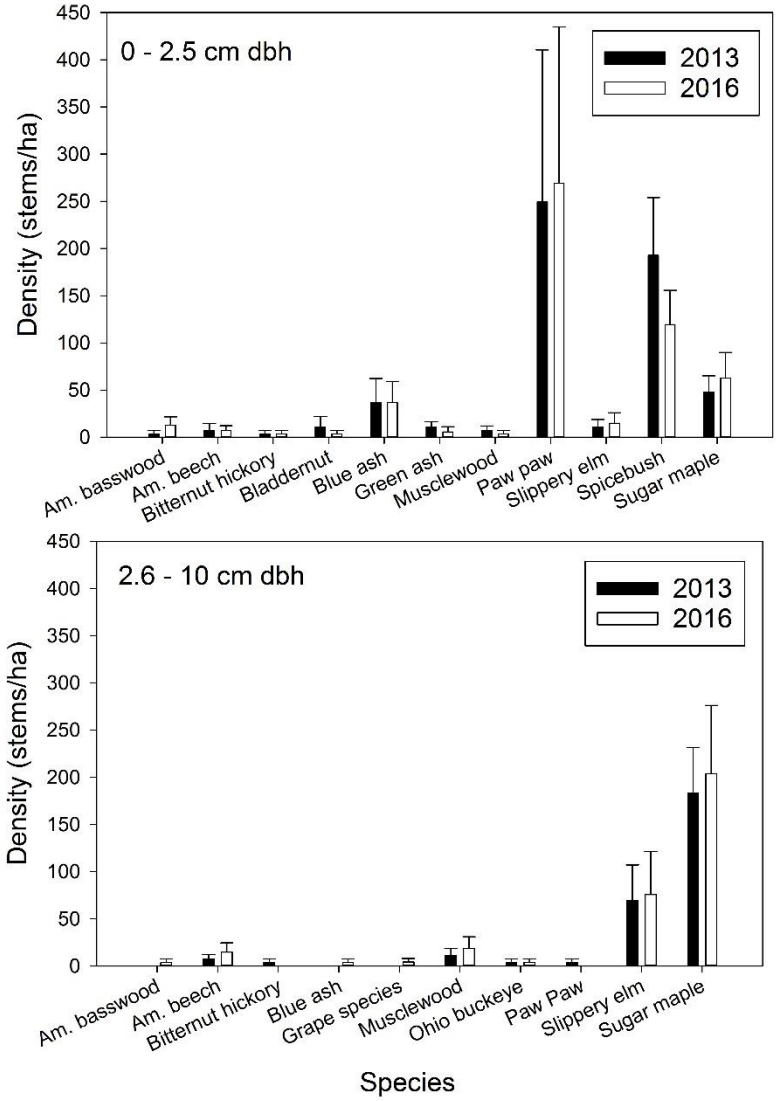

Figure 6. Density (mean ± 1 SE) of small (≥ 1m height; 0-2.5 cm dbh) and large (2.6-10 cm dbh) saplings at Eagle's Crest NP in 2013 and 2016.

Spring Pond

Between 2013 and 2016, the density of small seedlings at Spring Pond NP did not change (131 ± 26 stems/100 m^2 in 2013 vs. 135 ± 36 stems/100 m^2 in 2016; p = 0.90) with green ash continuing to dominate the stratum (Figure 7). However, the number of species tallied in this

stratum increased from 11 in 2013 to 18 in 2016 with 8 species gained and one species lost. Of the species gained, seven were native and one was a non-native species.

Similar to small seedlings, the large seedling stratum at Spring Pond NP exhibited little change (485 ± 67 stems/100 m^2 in 2013 vs. 482 ± 54 stems/100 m^2 in 2016; p = 0.97). This layer continued to be dominated by green ash and spicebush (Figure 9). The number of tallied species increased from 14 in 2013 to 20 in 2016 with one species lost and seven species added. Of the added species, five were native and two were non-native.

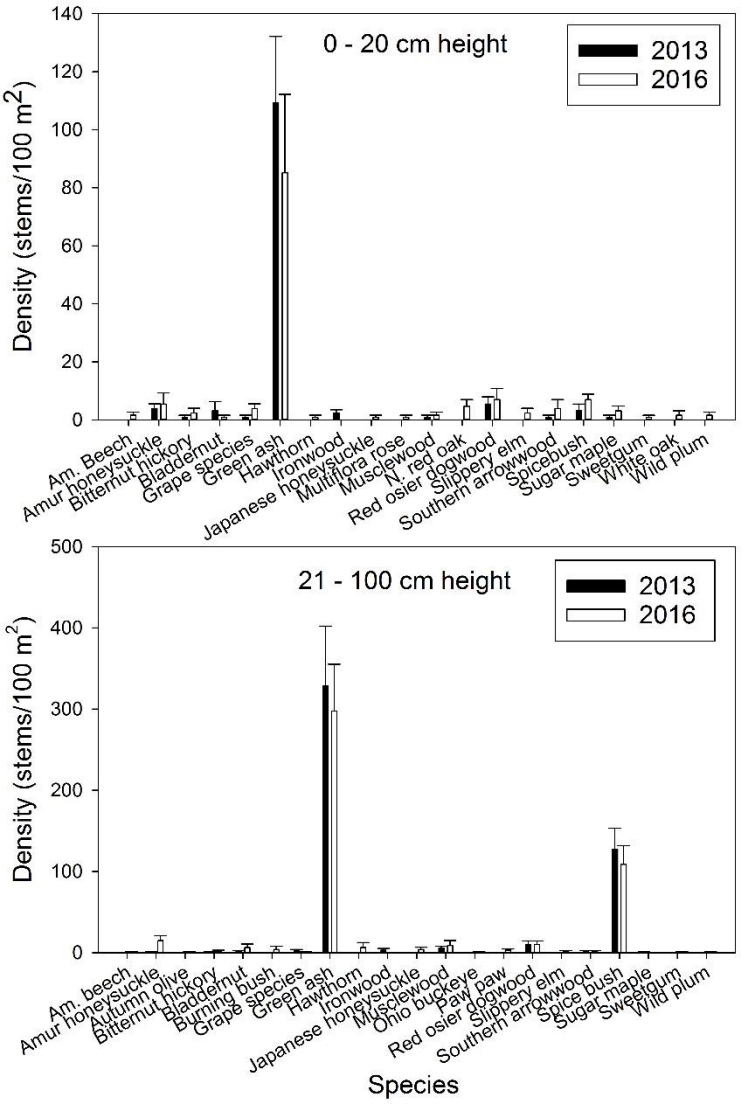

Figure 7. Density (mean ± 1 SE) of small (0-20 cm height) and large (21-100 cm height) woody seedling by species at Spring Pond NP in 2013 and 2016.

Unlike the seedling layer, the sapling layer exhibited a large increase in density. Among small saplings (≥1 m height, 0-2.5 cm dbh), density nearly doubled from 1208 ± 225 stems/ha in 2013 to 2374 ± 312 stems/ha in 2016. This increase in density was largely a result of a five-fold increase in the density of spicebush. Changes were less dramatic in the the large sapling stratum (2.6-10 cm dbh). While density increased from 408 ± 58 stems/ha in 2013 to 517 ± 70

stems/ha in 2016, this change did not approach statistical significance (p = 0.13). While the density of most species in this layer were similar between 2013 and 2016, the density of paw paw nearly doubled (Figure 8).

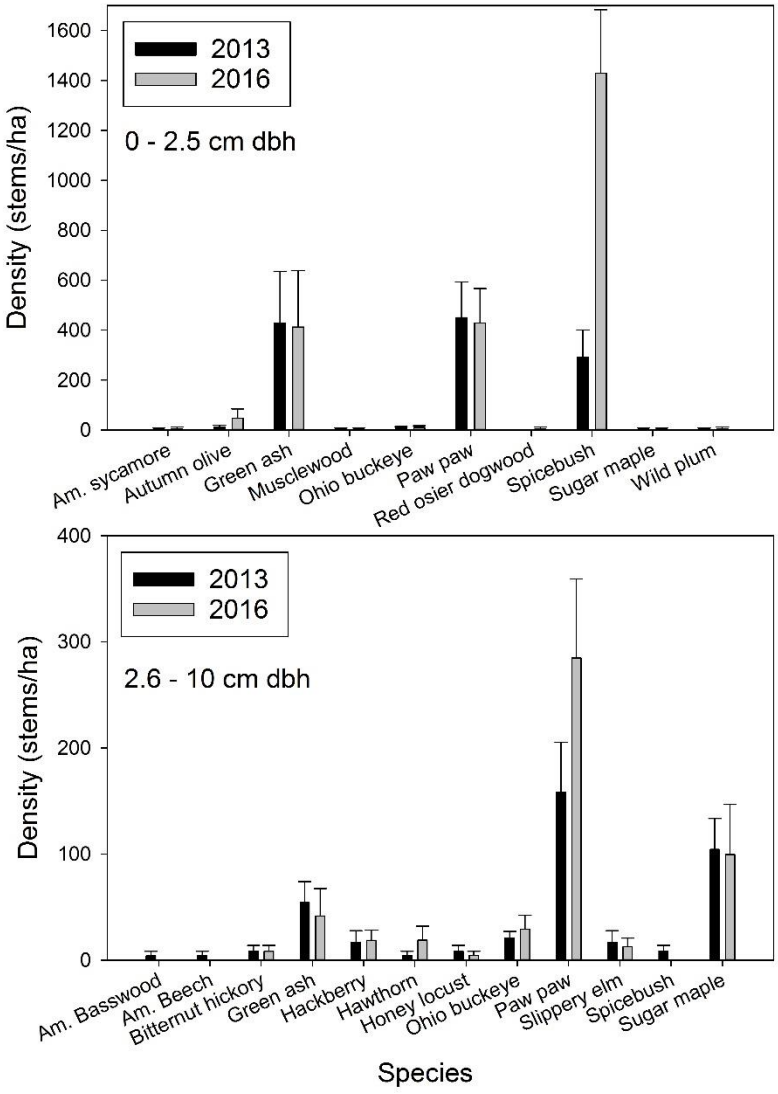

Figure 8. Density (mean ± 1 SE) of small (> 1m height; 0-2.5 cm dbh) and large (2.6-10 cm dbh) saplings at Spring Pond NP in 2013 and 2016.

The observed increases in the density of spicebush and paw likely resulted from the heavy mortality of green ash in the canopy of Spring Pond NP (Figure 9) resulting from the emerald ash borer (EAB). While the Preserve previousy had a more open canopy compared to Eagle's Crest NP, with the loss of large green ash trees much of the site now lacks overstory shading. Paw paw is highly unpalatable to deer and has been shown to increase in density with increased deer abundance as more palatable species are consumed (Slater and Anderson

2014). Although spicebush is browsed when overabudant deer have exhausted other woody species, the species is generally not suppresed by browsing (Liang and Seagle 2002). Based upon the post-EAB increase in the density of these species, it is likely that increased light levels fostered increased clonal reproduction and growth rather than reductions in deer abundance.

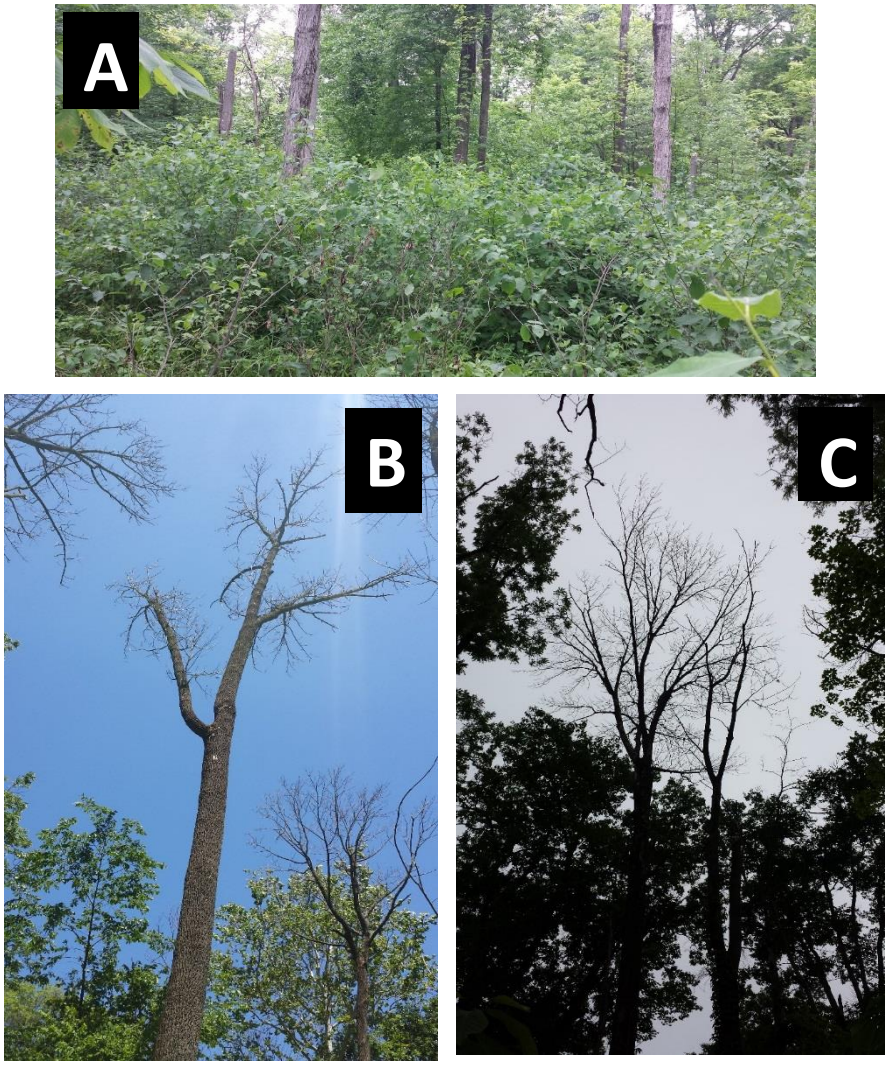

Figure 9. (A) Thicket of spicebush at Spring Pond NP. (B and C) Spring Pond NP has experience heavy mortality of green ash as a result of infestation with emerald ash borer. This mortality has created large areas throughout the Preserve with no canopy cover.

Browsing of woody plants

Overall, the percent of twigs browsed at Eagle's Crest NP did not change between 2013 and 2016 (28.9 ± 7.1% in 2013 vs. 26.3 ± 8.9 in 2016; $p = 0.79$). Browse rates were very similar in 2013 and 2016 for most species (Figure 10), with the exception of bladdernut (*Staphylea trifolia*) and Ohio buckeye (*Aesculus glabra*). Browse on both of these two species was assessed on one plant on one plot in 2013, which contributed little to the calculation of overall browse rates. Percent browse decreased significantly at Spring Pond NP ($p = 0.04$), declining from 77.4 ±

3.3% in 2013 to 68.4 ± 3.6%. When assessing browse, I made no attempt to determine whether browsing on a twig occurred before or after the last sampling in 2013. Therefore, this was an assessment of all browse on a site, not new browse that occurred since the last sampling. Therefore, true post-2013 browse rates may be lower than what I calculated in this report.

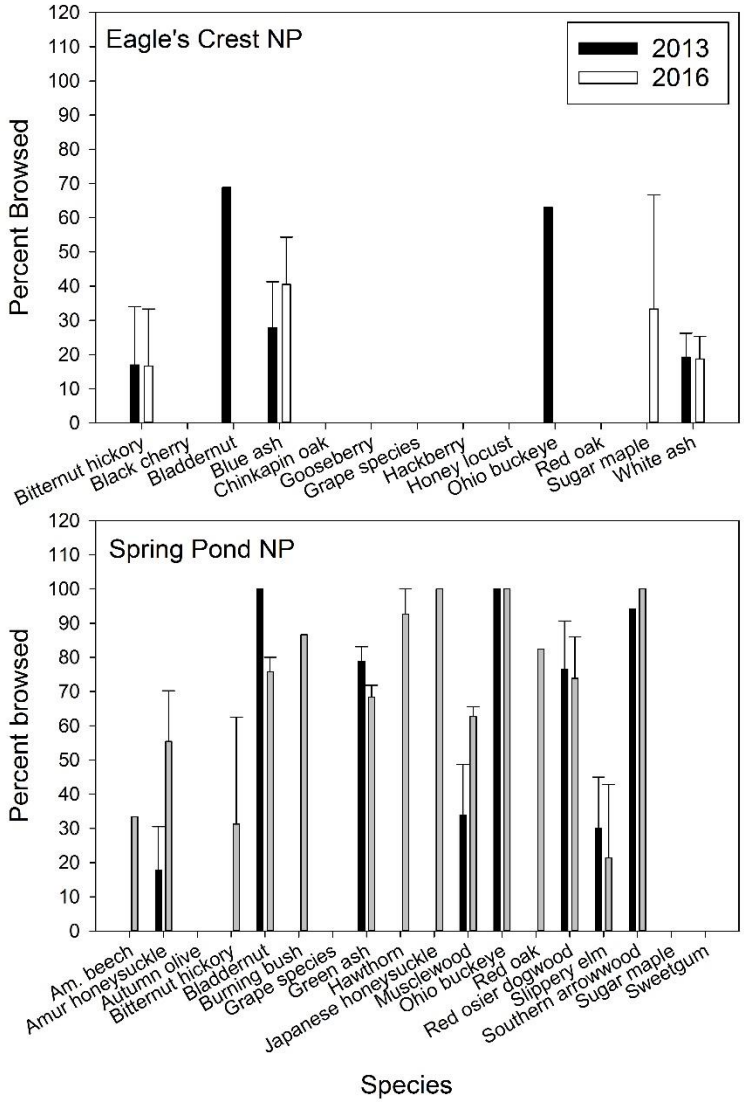

Figure 10. Percent (mean ± 1 SE) of twigs browsed by species at Eagle's Crest and Spring Pond Nature Preserves in 2013 and 2016.

Conclusions

Following the 2014 reduction in deer abundance, I observed an increase in the heights of jack-in-the-pulpit and white baneberry, two indicator species of deer overabundance in Indiana (Webster and Parker 2000). I also observed large increases in the density of small ash and sugar maple seedlings. Browse rates remained constant at Eagle's Crest NP, but were significantly lower at Spring Pond NP, the site that exhibited greater rates of browse in 2013. These results suggest that the reduction in deer abundance has had a positive effect on vegetation communities in Eagle Creek Park. However, multiple environmental factors contribute to annual changes in plant growth and reproduction and caution should be applied when interpreting a single year of results. Therefore, continued monitoring is needed to track long-term trends resulting from reductions in deer abundance. While deer populations typically rebound quickly after a single hunt, a study in Indiana State Parks has shown that the long-term management of deer abundance can lead to the sustained recovery of vegetation communities (Jenkins et al. 2014).

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Cover page: Left-female jack-in-the pulpit plant in fruit at Eagle's Crest Nature Preserve; Center-mature green ash trees killed by emerald ash borer in Spring Pond Nature Preserve; Right-Prairie trillium (*Trillium recurvatum*) in fruit at Eagle's Crest NP.